Evaluating the Implications of Watershed Change on Stream Conditions and Aquatic Habitat

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Abstract

To inform the process of local land-use planning 3 future development scenarios (planned trend, conservation, and moderate alternatives) were evaluated for their effects on terrestrial wildlife habitat. Land cover was mapped from existing sources; 12 land-cover and 3 stream-channel classes were used to depict habitat conditions in the watershed. Future landscape condition was modeled by assigning "footprints" to undeveloped parcels based on zoning density and lot size. Assumptions focused on how different land use patterns affect forest seral-stage. Wildlife-habitat relationship models were constructed for 9 species including the red-legged frog, western toad, Douglas squirrel, bobcat, downy woodpecker, pileated woodpecker, willow flycatcher, blue grouse, and great blue heron. Habitat quality was evaluated based on vegetation type, patch configuration, and home-range size. Species models were run on current and future land covers. Landscape changes that applied to nearly all species under the planned trend include: 1) a decrease in the total amount of habitat available; 2) an increase in fragmentation (i.e. an increase in the number of patches with a corresponding decrease in patch size); and 3) an overall decrease in habitat quality, with consistent loss of primary breeding and foraging habitats. Landscape changes under the conservation alternative were intermediate between current conditions and the planned trend. The moderate alternative uses the concepts of large blocks of land and wildlife corridors to mitigate the effects of planned trend development.

Introduction

Current land-use plans in the Puget Sound region do not adequately protect watershed functions and natural resources. Urbanization of the Puget lowlands has resulted in the degradation of water quality and habitat for fish and wildlife. As the region's forests are cut down and replaced by houses, roads, and shopping malls, natural ecosystems are measurably diminished due to the physical, chemical and biological impacts of impervious areas and urban stormwater runoff. Urbanization permanently changes the hydrology of a watershed with increases in both the rate and the total volume of runoff. This increased runoff causes stream bank erosion, channel scouring and downstream sedimentation. Kitsap County's local streams are dependent on groundwater for baseflows; the loss of groundwater recharge due to increased impervious land cover causes concern for water availability and may result in lower than normal summer stream flows.

The diffuse nature of watershed degradation in urban and urbanizing areas is extremely difficult to correct and prevent and it is increasingly recognized that new approaches to land use planning methods are required to determine planning decisions based on impacts to habitat and other watershed functions. Planners and resource managers are looking for tools to improve the local planning process to meet federal and state mandates for water quality and habitat.

Alternative Futures

Kitsap County has developed a demonstration watershed/community-planning model in the Chico Watershed. This pilot project applied technical analysis to watershed functions and used this information in a public education and planning process to create and evaluate alternative future build-out scenarios of the watershed. Kitsap County calls this model Planning by Watershed. It is based on alternative futures planning efforts conducted on the Muddy Creek watershed and the Willamette River watershed in Oregon (Hulse et al. 2000 and 2002).

Using GIS and other analysis tools, scientists, educators and citizens from the watershed were able to describe and analyze three alternative futures for the Chico creek watershed (Nelson 2003). These scenarios allowed planners to identify trends over time and space to determine which alternative would most likely provide natural resource protection while the watershed developed into the future. Each of the scenarios described below, was assumed to be built out to full capacity, relying on vacant parcels and population to drive the plan as opposed to a set time in the future. This was intended to provide analysis of the ultimate affects of each scenario on the natural resources in the watershed.

The Planned Trend Scenario assumes full build-out of existing parcels within the Chico Watershed under current regulations and existing zoning. This scenario intends to illustrate what would happen if current plans became future realities and attempts to show the full effects that existing regulations will have on the overall health of the watershed.

The Conservation Scenario seeks to minimize impacts on the natural environment by reducing the amount of future land development and concentrating development in areas that are least sensitive to land-use change.

The Moderate Scenario seeks to minimize impact on the natural environment while allowing for growth in areas that could accommodate it. It intends to balance the need for protecting natural resources and watershed functions with the reality that some level of development will occur over time.

Chico Watershed History
Beginning in the late 1800's, the forests of the Chico watershed were harvested, at first to make room for homesteaders and shortly after for the timber resource. It appears that most of the watershed was cleared at one point in time and in many places the forests have been harvested several times. These harvests included the riparian areas for most creeks in the watershed

Over the past hundred years, property in the Chico watershed has been developed, with most of this development occurring around Kitsap and Wildcat lakes and the lowest two miles of Chico Creek. Roads and commercial areas were built to serve this area and over time the Chico watershed has changed from an old growth forest to a patchwork of development and second, third or forth generation forests. The creek has been manually straightened and armored in many reaches and historically the stormwater running off impervious areas was piped directly into the lakes or creeks.

The combined effects of land use change, road construction and forest harvest have left their mark on the morphology and aquatic habitat of the Chico watershed stream network. Where development has occurred, the creek is usually disconnected from its floodplain. These reaches are entrenched, have unstable banks, have reached some level of cementation and usually are surrounded by an immature, narrow riparian corridor that includes a variety of exotic and invasive vegetation. Culverts and bridges have inhibited the natural movement of sediment and large woody debris, creating localized areas of material excess and starvation.

However, where forested lands still remain, and riparian corridors are being managed, the creeks seem to be recovering from past disturbance and functioning stream reaches provide us with reference aquatic habitat conditions for this watershed. These reaches occur mainly in the upper parts of Wildcat, Lost and Dickerson creeks. Kitsap and Wildcat lakes buffer storm flows and provide a degree of protection to the stream reaches immediately downstream of the lakes.

Purpose
This paper describes the approach used to project future change to existing aquatic habitat and summarizes the results of these potential impacts. Coincident analyses of terrestrial habitat (Linders and Wilhere 2003), geomorphology (Segura-Sossa et al. 2003), water quality, water quantity and riparian processes (Roberts 2003), as well as a project overview (Nelson 2003) provide a broad description of the effects of alternative future development scenarios on the natural resources of the Chico Creek watershed.

Methods
A synthesis of assessment data and analytical products was used to qualitatively describe potential changes to aquatic habitat for each of the alternative scenarios.

Data
The creek network in the Chico watershed was surveyed from May to September 2002, gathering both quantitative and qualitative data for most of the low gradient stream reaches in the watershed, including wood counts, bankfull measurements, cross sections, longitudinal profiles, pebble counts. Additional parameters considered in this analysis were grouped into six major elements: habitat, habitat access, watershed condition (sediment inputs), channel condition, hydrology, and water quality. The status of each major element was determined by assessing the condition of indicators identified in the National Marine Fisheries Service matrix of pathways and indicators (NMFS 1996). Figures 1-6 describe classification of each tributary as properly functioning, at risk, or not properly functioning.

Rapid Assessment
A rapid assessment rating determined the general state of watershed function in Chico Creek and it's main tributaries (Henshaw et al. 2000). The rapid assessment was replicated independently and a comparison study was completed for all reaches in the study area, by the Center for Water and Watershed Studies at the University of Washington (Segura-Sossa 2003). The most intact and healthy reaches in the watershed, and the most degraded reaches were used as reference sites when describing and rating 8.8 miles of creek in the watershed. Reaches were given a score of 1 to 4 for Complexity,

Stability, Cementation and Riparian condition. Categorical scores were added together for each reach with the total final score ranging from 4-16. The range of scores was divided and labeled, with reaches scoring between 4 and 8 considered to be **Not Functional** habitat for aquatic species, reaches scoring between 9 and 12 considered to be habitat that is **At Risk** of becoming not functional, and reaches scoring between 13 and 16 are considered to provide **Functional** habitat for aquatic species (see Map 1).

LWD Recruitment Potential

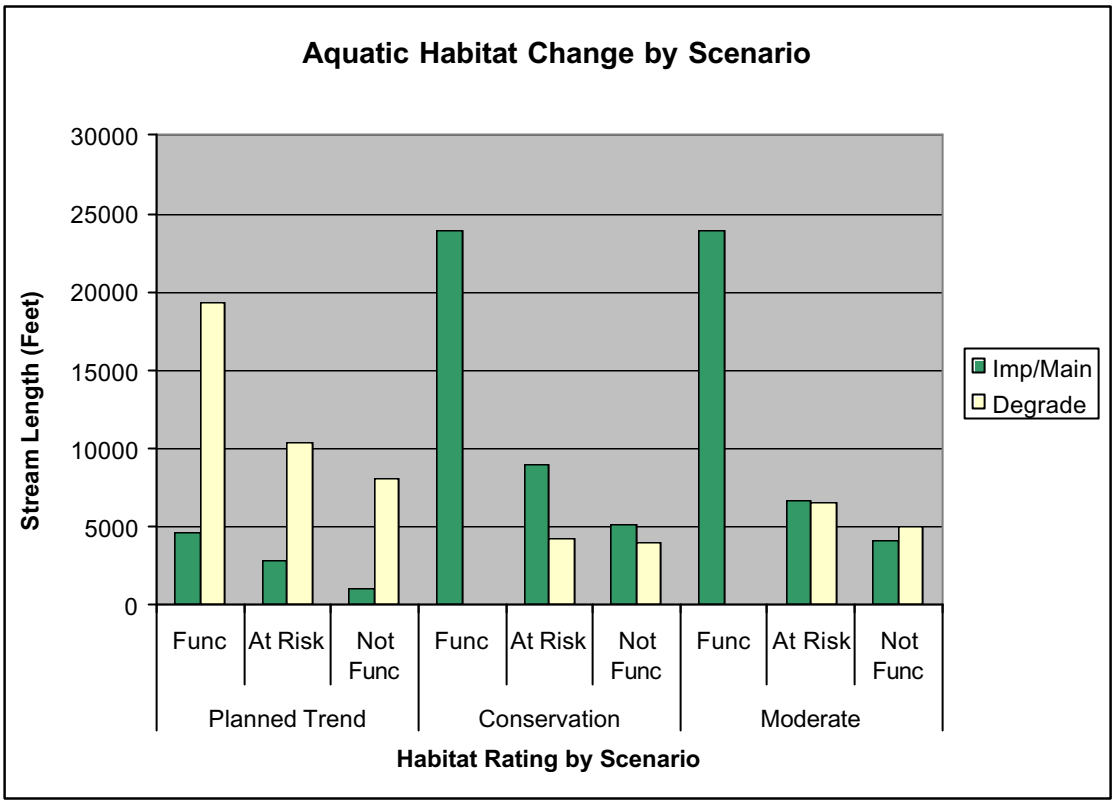
Large Woody Debris (LWD) recruitment potential for the study reaches was developed for a 500-foot buffer around the study area. Recruitment potential varied throughout the watershed, with the highest potential for recruitment occurring above the Navy owned railroad tracks, and lowest potential recruitment occurring within the urbanizing reaches below the railroad tracks (Roberts 2003).

Land Cover

To describe current and potential future land use, relationships between land use and impervious surface, dwelling units, and forest cover were developed based on existing conditions in Kitsap County. Initial data was based on the Kitsap County Comprehensive Plan designations and various GIS datalayers developed and maintained by Kitsap County GIS staff, including the parcel base map, current land use from the Assessor's Office, and current land cover data within 5-meter squares. Scenario designations were developed and future land use was interpreted. It was assumed that the impervious area associated with roads did not increase significantly under any of the scenarios. Although infrastructure development may occur, the surfaces represented by current forest roads represent those future surfaces adequately for the modeling methods that we are using. Table 1 describes impervious surface coefficients used to determine future surface amounts at build-out were determined on a countywide average to produce as large a sample set as possible.

Table 1. Impervious surface coefficients (Source Kitsap County GIS).

% Imp	Planning Designation	% Imp	Planning Designation	% Imp	Planning Designation
56.72%	auto hiway	3.62%	open land	58.79%	urban high
61.18%	commercial retail	44.94%	parking	21.79%	urban low
46.90%	commercial service	7.73%	parks	45.09%	urban medium
9.84%	Estate	8.07%	power	38.47%	urban standard
18.00%	Facilities	15.97%	rail	32.09%	utilities general
26.95%	Gas	41.55%	right of way	6.20%	vacant
53.48%	industrial general	8.04%	rural	18.96%	water
28.59%	industrial light	29.63%	schools	2.58%	wooded
25.67%	Mines	27.28%	streets highways		
40.49%	mobile park	13.04%	suburban		



Projecting Future Conditions

GIS tools were used to delineate the Chico watershed into 13 sub-watersheds. Next, the change in impervious area within each sub-watershed was determined for each scenario. Existing habitat conditions and LWD recruitment potential were used to define aquatic species sensitivities and concerns and then compared to changes in impervious area within each sub-watershed. From this assessment, anticipated future conditions were qualitatively determined for each alternative scenario.

Results

The graph below illustrates the change to existing Functional, At Risk and Not Functional habitat under full build-out of the three alternative future scenarios. Habitat that was either improved or maintained into the future was graphed together, while habitat that degraded into the future was graphed separately. The four maps at the end of this document illustrate the anticipated change to existing conditions by sub-watershed and give a spatial description of change within the Chico watershed.

Planned Trend

Full build-out of the Planned Trend scenario would degrade the most aquatic habitat in the Chico watershed. Under this scenario, the majority of the existing functional habitat would be degraded to some degree, with less than 5000 feet of good habitat being maintained. In addition, most of the habitat that is currently at risk of becoming not functional is degraded. And under this scenario, even the most degraded habitat continues to degrade. The take home message is that under Kitsap County's current plan for the Chico watershed, aquatic habitat is degraded throughout the watershed.

Conservation

Full build-out of the Conservation scenario provides protection to watershed function by limiting development within the forested portions of the watershed. The result of these protections is improvement and maintenance of all the functional habitat in reaches studied and protection of roughly two-thirds of habitat currently at risk. The Conservation scenario was the only scenario that showed improvement in a not functioning reach.

Moderate

The Moderate scenario directed development away from areas where functional habitat currently exists and to areas where aquatic habitat is already not functional. This resulted in improvement or maintenance of all the existing functional

habitat in the study area, and further degradation of some at risk and not functional habitat. Protecting existing functional habitat may be the most effective and efficient means of recovering salmon. The moderate approach provides that protection to the Chico watershed.

Assumptions

The results of this analysis are based on several assumptions made during the development of the scenarios. It was assumed in the Conservation and Moderate scenarios, that development rights were either purchased or transferred out of the forested areas of the watershed and that in the Planned Trend, all those forested lots were developed. It was assumed that low impact development techniques incorporated too much of the new development in the Conservation and Moderate scenarios, and it was also assumed that these techniques provide the protections and reduction in stormwater that they are intended to provide. It was also assumed that no restoration activities took place in any of the scenarios.

The following summaries describe aquatic resource sensitivities and concerns as well as the anticipated future conditions for each of the three scenarios. These results are illustrated in Maps 2-4.

Wildcat Creek Aquatic Resource Sensitivities and Concern

- Wildcat Lake buffers the transport of sediment bedload, LWD, and changes in peak runoff caused by land-use change in the sub-watershed.
- The culvert at Wildcat Lake Road is a complete barrier to juvenile and adult passage at low and a partial barrier at high flows and inhibits the natural routing of sediment and LWD through the reach.
- Reaches below the Wildcat Lake Road culvert are generally in very good condition. However, habitat in these reaches are fragmented at summer low flows due to sediment aggradation, and there is evidence of sediment pool filling.
- Reaches in this sub-watershed, particularly along the Mountaineers property, are highly productive habitat for chum and coho salmon.
- Increases in peak flow runoff from the northern tributaries of mid-Wildcat, could increase both hydraulic energy and sediment input to the downstream reaches of Wildcat and Upper Chico.
- Steep slopes along mid Wildcat creek are highly sensitive to mass wasting caused by sudden changes in forest hydrology and hillslope disturbance.

Upper Wildcat Sub-watershed

Anticipated Future Conditions of the Moderate Scenario in Upper Wildcat

Land-use change in upper Wildcat would include more intense development around Wildcat Lake. Increased development density around the lake would likely contribute to degradation of upstream tributaries and wetlands. An increase in pollutant loadings to the lake through stormwater runoff is likely. While Wildcat Lake would buffer changes in the downstream hydrograph, some water quality degradation from nutrient, pathogen, and chemical nonpoint sources is expected. **Future aquatic resource conditions are likely to degrade from the current level of proper function.**

Anticipated Future Conditions of the Conservation Scenario in Upper Wildcat

Land-use change in upper Wildcat will be minimal. Under this scenario, parcels are aggregated under common ownership and commercial forest properties will not receive residential units, reducing the number of new units built around the lake. Wildcat Lake will buffer the effects of build out to the upper reaches of Wildcat creek. **Future aquatic resource conditions will likely maintain properly functioning conditions.**

Anticipated Future Conditions of the Planned Trend Scenario in Upper Wildcat

Full build out of this sub-watershed includes filling all vacant lots, including meeting residential density capacity for all parcels zoned for commercial forest harvest. Future development and associated road construction would likely increase pollutant and fine sediment loads as well as alter the hydrology of the tributaries and wetlands around the lake. **Future aquatic resource conditions are likely to degrade from the current level of proper function.**

Mid-Wildcat Sub-watershed

Anticipated Future Conditions of the Moderate Scenario in Mid Wildcat

Land-use change in mid-Wildcat is minimal, with most of the land remaining forested. Incentives will be used to encourage low impact development techniques in the designated wildlife corridor. Some development rights may be purchased to reduce future development densities. Pollutant loadings from stormwater and sedimentation impacts should be reduced through low impact development techniques. **It is expected that existing properly functioning aquatic resource conditions would be maintained into the future under this scenario.**

Anticipated Future Conditions of the Conservation Scenario in Mid Wildcat
Under this scenario all lots under common ownership are aggregated and allowed one unit per parcel. This assumption drastically reduces the level of future development in this sub-watershed. Existing Forest and Fish rules would provide adequate protection and given time would allow recovery of riparian function, including consistent recruitment of LWD. **Future aquatic resource conditions are likely to improve in these reaches under this scenario.**

Anticipated Future Conditions of the Planned Trend Scenario in Mid Wildcat
Full build out of this sub-watershed includes filling all vacant lots, including meeting residential density capacity for all parcels zoned for commercial forest harvest. Future development and associated road construction would likely increase pollutant and fine sediment loads as well as increase volumes of storm water to the creek. **Future aquatic resource are likely to degrade from current properly functioning conditions.**

Lower Wildcat Sub-watershed
Anticipated Future Conditions of the Moderate Scenario in lower Wildcat
Land-use change in lower Wildcat includes development of currently vacant residential lots. A large portion of this sub-watershed is contained within a designated wildlife corridor. The Mountaineers property is expected to remain in a conservation status. Potential pollutant and fine sediment loads, as well as increased volumes of stormwater would likely occur from development of parcels surrounding ephemeral tributaries. The level of protection given to ravine slopes will largely determine coarse sediment inputs. The stream reaches in this sub-watershed are currently properly functioning. **These conditions would be maintained and with riparian replanting and LWD recruitment near the confluence, the lower reach may be improved in the future.**

Anticipated Future Conditions of the Conservation Scenario in lower Wildcat
Under this scenario all lots under common ownership are aggregated and allowed one unit per parcel, and vacant rural residential lots are developed. This assumption reduces the level of future development in this sub-watershed. **It is expected that the current properly functioning condition of these creek reaches will absorb additional loadings from development near ephemeral tributaries and maintain its current condition.**

Anticipated Future Conditions of the Planned Trend Scenario in lower Wildcat
Full build out of this sub-watershed includes filling all vacant lots, including meeting residential density capacity for all parcels zoned for commercial forest harvest. Future development and associated road construction will likely increase pollutant and fine sediment loads as well as increase volumes of storm water to the creek. **Future aquatic resource conditions are likely to degrade from the current level of proper function.**

Lost Creek Aquatic Resource Sensitivities and Concern

- Large volumes of sediment have been introduced into the lower reaches of this sub-watershed. In the upper reaches, bedload input appears high and is transported with high energy causing some channel scour and bank erosion.
- The large number of forest road crossings and high road densities throughout this sub-watershed deliver storm flows and fine sediments directly to the creek.
- Mass wasting events within the confined reaches of the creek have contributed sudden loads of both fine and course sediments.
- Riparian vegetation in the upper half of this sub-watershed consists mainly of immature deciduous trees.
- Reaches throughout this sub-watershed provide highly productive habitat for chum and coho salmon.

Anticipated Future Conditions of the Moderate Scenario
Purchasing development rights from forest lots and retaining them in commercial forestry would minimize land-use change in Lost Creek. Less than ten additional units would be developed on existing vacant lots. Forest road densities would be reduced through current Forest and Fish rules. Future pollutant loadings would be reduced in this sub-watershed with a reduction in stream crossings and more protective riparian management. **Full implementation of Forest and Fish rules could result in improved aquatic resource conditions within this sub-watershed.**

Anticipated Future Conditions of the Conservation Scenario
Under this scenario all lots under common ownership are aggregated and allowed one unit per parcel. This assumption drastically reduces the level of future development in this sub-watershed. The stream reaches in this sub-watershed currently function properly, yet existing Forest and Fish rules would allow recovery of riparian function, and given time improve LWD recruitment. **Future aquatic resource conditions are likely to improve in these reaches under this scenario.**

Anticipated Future Conditions of the Planned Trend Scenario
Full build out of this sub-watershed includes developing all vacant lots, including meeting residential density capacity for all parcels zoned for commercial forest harvest. Future development and associated road construction would likely increase pollutant and fine sediment loads as well as increase volumes of storm water to the creek. **Future aquatic resources are likely to degrade from their current properly functioning condition.**

Dickerson Creek Aquatic Resource Sensitivities and Concern

- Large volumes of sediment have been introduced into this reach. In confined reaches, ravine slopes are unstable and actively eroding. Upstream bedload input appears high.
- Fragmentation of habitat in summer months due to streambed aggradation and low base flows is a concern.
- The Navy Railroad culvert is a partial barrier for fish passage at low and high flows and inhibits natural routing of sediment and LWD.
- LWD that is recruited and transported through the reach is removed at downstream culverts.
- The powerline right-of-way has eliminated riparian structure and de-stabilized slopes directly adjacent to the stream. This slope is a reliable source of both fine and course sediments during mass wasting events and from general storm runoff.
- Below the Navy Railroad culvert the creek becomes entrenched, running through residential development, where riparian vegetation has been removed reducing LWD recruitment and limiting aquatic habitat.
- Below the Navy Railroad culvert, storm flows are concentrated due to bank armoring of entrenched channels. High velocities scour beds, erode banks, limit refuge for juveniles and degrade spawning habitat.

Anticipated Future Conditions of the Moderate Scenario
Land-use change in Dickerson Creek would be minimized through purchase or transfer of development rights and forested parcels would retain commercial forestry designation. Forest road densities would be reduced through current Forest and Fish rules. Future pollutant loadings would be reduced in this watershed through a reduction in road and stream crossings and through more protective riparian management, especially in reaches below the railroad culvert. Full implementation of Forest and Fish rules could result in improved aquatic resource conditions within this sub-watershed. **It is expected that both existing properly functioning conditions in upper Dickerson and degraded conditions in lower Dickerson would be maintained into the future under the moderate development scenario.**

Anticipated Future Conditions of the Conservation Scenario
Under this scenario all lots under common ownership are aggregated and allowed one unit per parcel. This assumption drastically reduces the level of future development in the upper reaches of this sub-watershed, however vacant rural residential lots below the railroad crossing would be developed. **Without physical restoration of the railroad culvert and powerline right-of-way, it is expected that both existing properly functioning conditions in upper Dickerson and degraded conditions in lower Dickerson would be maintained into the future.**

Anticipated Future Conditions of the Planned Trend Scenario
Full build out of this sub-watershed includes filling all vacant lots, including meeting residential density capacity for all parcels zoned for commercial forest harvest. Future development and associated road construction would likely increase pollutant and fine sediment loads as well as increase volumes of storm water to the creek. Sediment and LWD would continue to aggrade behind the railroad culvert, increasing bank erosion. **Future aquatic resource conditions are likely to degrade throughout Dickerson creek under this scenario.**

Kitsap Creek Aquatic Resource Sensitivities and Concern

- Kitsap Lake buffers the transport of sediment, LWD, and changes in peak runoff to Kitsap Creek.
- The Northlake Way culvert is a partial barrier at both low and high flows. The culvert is also partially responsible for the instability and lack of LWD in the reach immediately below the lake.
- Throughout Kitsap Creek, removal of LWD and armoring of streambanks has resulted in physical instabilities and loss of habitat complexity.
- Roads and residential development west of the stream have eliminated most of the riparian vegetation, and it appears that any LWD that makes it to the creek is removed.
- Kitsap Lake discharges warm water in the summer and the lack of riparian vegetation and habitat structure exacerbates thermal problems and impairs summer rearing.
- Deteriorating water quality in Kitsap Lake is expected with additional development within the watershed.
- Wetland function and habitat access will degrade as roads and residential development surround the lake and wetland complex at the south end of Kitsap Lake.

Anticipated Future Conditions of the Moderate, Conservation and Planned Trend Scenarios
Extensive land-use changes are expected in this sub-watershed with almost 400 acres of forest adjacent to Kitsap Lake being developed into high density mixed land use. Vacant lots developed around the lake, some at urban densities within the City of Bremerton, and associated storm-water loadings are expected to further degrade lake water quality. Future development and associated road construction would likely alter the hydrology of the tributaries and wetlands around the lake. **Under all three scenarios, the existing degraded condition of aquatic habitat would continue to degrade.**

Upper Chico Creek Aquatic Resource Sensitivities and Concern

- Increases in storm flow runoff from the upper tributaries may increase both hydraulic energy and sedimentation into the downstream reaches of Upper Chico.
- Downstream of the Mountaineers property, where LWD counts are low, high-energy flows may incise the stream channel, further scouring already entrenched gullies.
- Aggregation of sediments above the Navy Railroad crossing has created an overly wide, shallow channel that is exacerbated by the loss of riparian function associated with the adjacent agricultural land use.
- The channel may stabilize and begin to recover functional habitat if LWD was established and riparian buffers were allowed to recover.

Anticipated Future Conditions of the Moderate Scenario
The upper Chico sub-watershed is likely to see little land-use change. Reduced sediment loading from Lost Creek is expected with full implementation of Forest and Fish rules, however development associated with the Wildcat Lake LAMIRD may increase pollutant and sediment loadings. **It is expected that both existing properly functioning conditions through the Mountaineers property and degraded conditions immediately upstream of the Navy railroad crossing would be maintained into the future under the moderate development scenario.**

Anticipated Future Conditions of the Conservation Scenario
The upper Chico sub-watershed is likely to see little land-use change. Reduced sediment loading from Lost and Wildcat creeks is expected with full implementation of Forest and Fish rules. The cumulative effects of improved riparian function from upstream would likely provide sufficient LWD to stabilize the creek channel and increase habitat structure throughout the sub-watershed.

It is expected that both existing properly functioning conditions through the Mountaineers property and degraded conditions immediately upstream of the Navy railroad crossing would improve.

Anticipated Future Conditions of the Planned Trend Scenario
The upper Chico sub-watershed is likely to see little land-use change. However the cumulative effects of development throughout the forested parcels of the Lost and Wildcat sub-watersheds would deliver pollutant loads, fine sediment and increased storm flows throughout these reaches. This would likely exacerbate entrenchment and bank erosion problems that currently exist upstream of the railroad crossing. **It is expected that conditions throughout these reaches would degrade under this scenario.**

Lower Chico Creek Aquatic Resource Sensitivities and Concern

- Stream crossings, bank armoring and associated entrenchment have resulted in loss of floodplain connectivity, which has impaired channel function and degraded aquatic habitat in all reaches downstream of the Navy railroad.
- Lack of adequate riparian recruitment and subsequent removal of LWD has resulted in physical instabilities and loss of habitat complexity.
- Roads and residential development have permanently altered the hydrology of lower Chico by removing riparian vegetation, reducing infiltration and directing storm flows directly to the creek.
- Culverts at Kittyhawk Lane, Highway 3 and Golf Course Hill Road inhibit routing of sediment and LWD, require annual maintenance of fish passage structures, and are a partial to full passage barrier during low and high flows.
- Naturally warm summer discharge from Kitsap Lake, loss of riparian shading and reduced interflow to the creek has prevented high instream temperatures from recovering during low flows in the summer.
- Sever entrenchment and armored banks, coupled with stormwater runoff piped directly to the creek has resulted in extreme scour of the creek bed and results in annual loss of spawning gravel and existing salmon redds, especially in the lowest mile of Chico Creek.

Anticipated Future Conditions of the Moderate Scenario
The lower Chico sub-watershed would build out remaining vacant lots. Low Impact Development techniques will be promoted in the north half of the sub-watershed, where increased densities will provide a receiving area for transfer of development rights. Increased pollutant loadings from storm-water would further degrade water quality in these reaches. Without stormwater retrofits and physical restoration of the floodplain, high-energy flows will continue to scour the creek bed and erode banks, preventing habitat structure from becoming established and removing spawning gravel and redds. **The cumulative effects of full build-out of the Moderate scenario will result in the continued degradation of aquatic species habitat in an already severely degraded section of Chico creek.**

Anticipated Future Conditions of the Conservation Scenario
Land-use changes in the lower Chico sub-watershed increase densities to accommodate growth that was reduced throughout the rest of the watershed from aggregating lots under common ownership. Stormwater volumes and associated pollutant and fine sediment loads would increase in this sub-watershed. High-energy flows would continue to scour the creek bed and erode banks, preventing habitat structure from becoming established and removing spawning gravel and redds. **Under this scenario, existing degraded condition of aquatic habitat would continue to degrade.**

Anticipated Future Conditions of the Planned Trend Scenario
Land-use changes in the lower Chico sub-watershed would build out remaining vacant lots. Increased pollutant loadings from storm-water could further degrade water quality in these reaches. Without stormwater retrofits and physical restoration of the floodplain, high-energy flows would continue to scour the creek bed and erode banks, preventing habitat structure from becoming established and removing spawning gravel and redds. **The cumulative effects of full build-out of this scenario will result in the continued degradation of aquatic species habitat in an already severely degraded section of Chico creek.**

Summary and Conclusions

Each of the main tributaries in the Chico watershed has a reach or series of reaches that has been determined to be at risk of becoming non-functioning. The future of these reaches will be determined, in large part, by the management and use of the land within the local drainage. Increased stormwater that is not properly managed, harvest practices that drastically alter the forest hydrology and the creation of more road crossings would most likely drive these reaches into a non-functioning state. However, through educated land use decisions and low impact development practices these reaches may not only be protected from further degradation, but may begin to recover as natural morphologic processes are allowed to recover.

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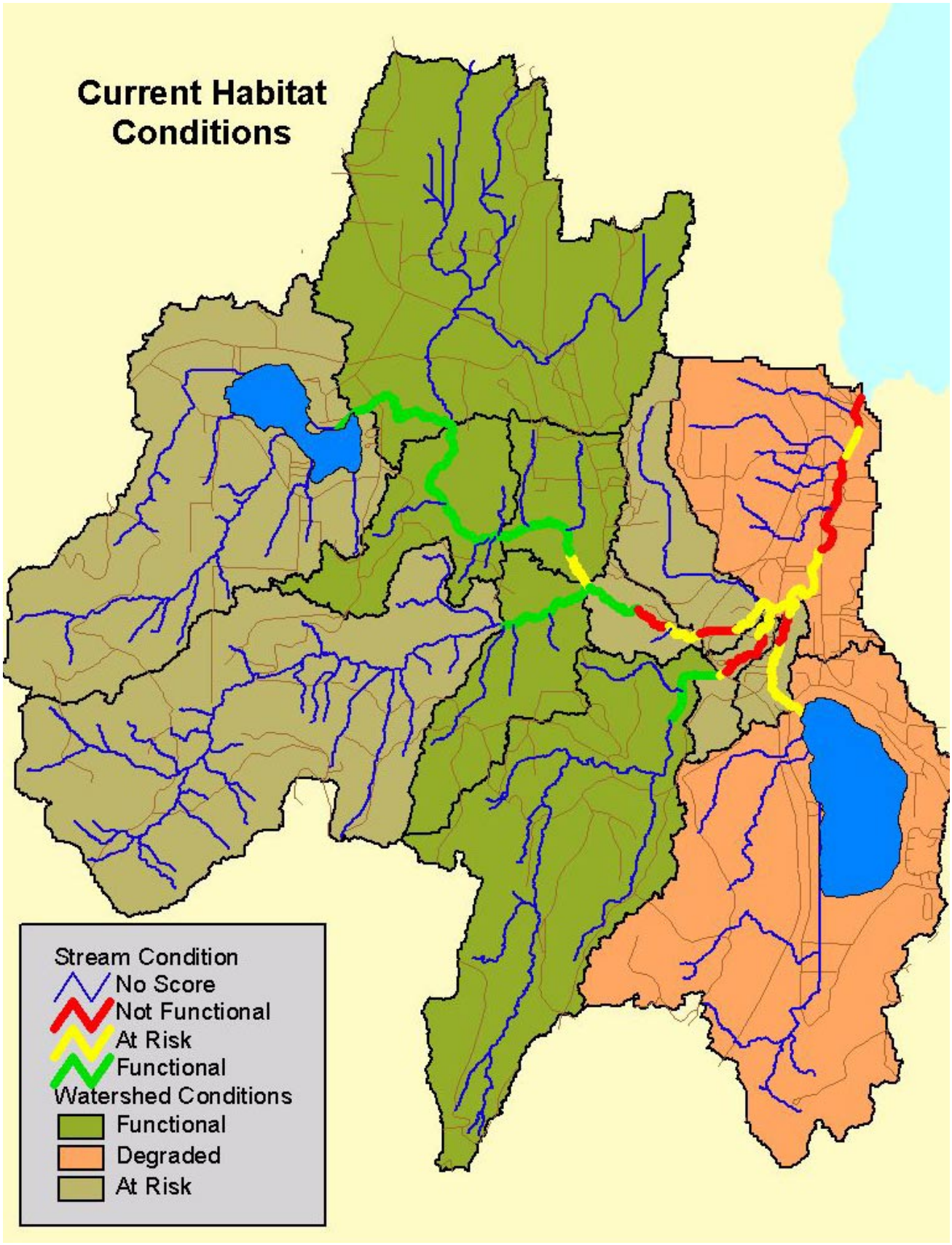
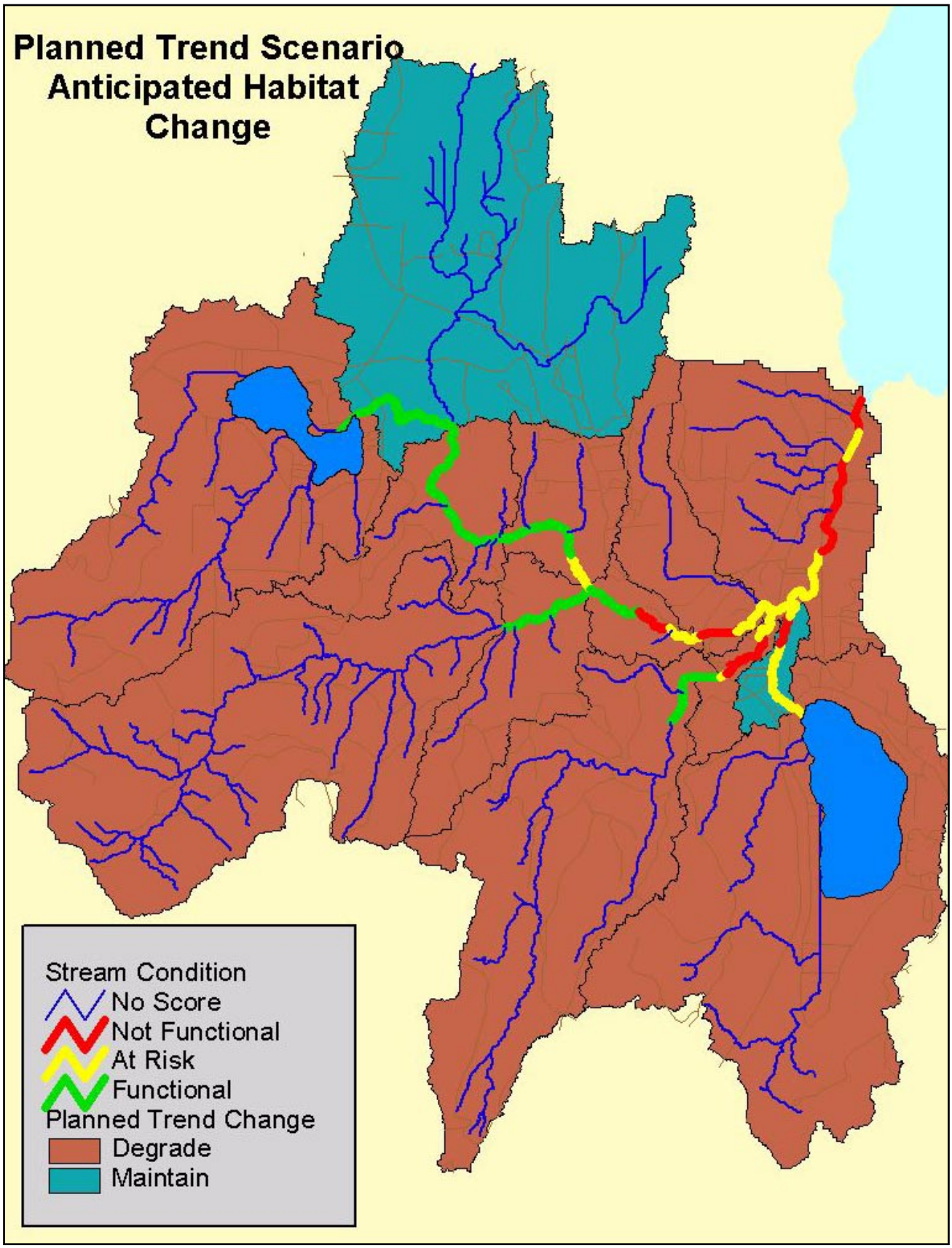
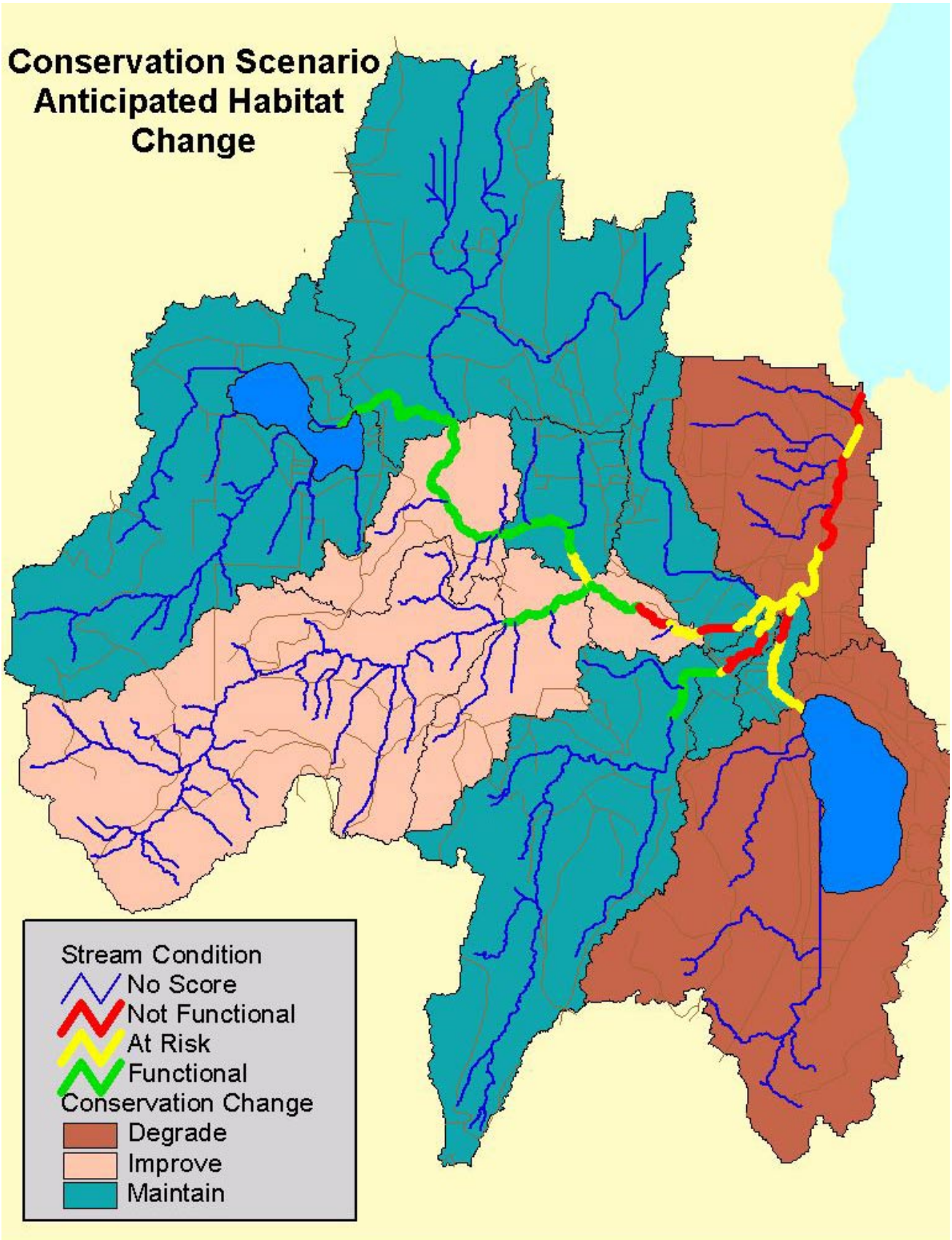
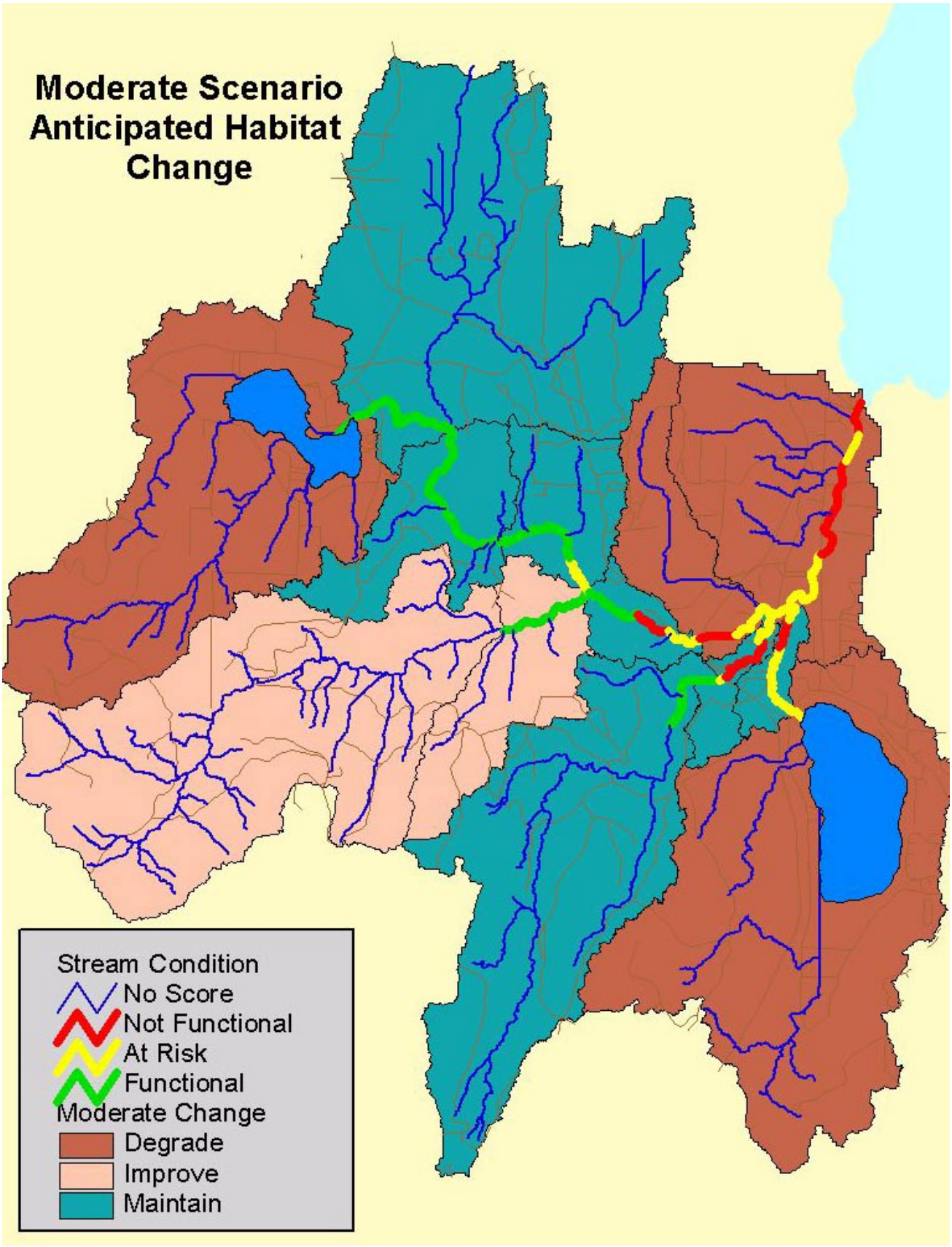

Current Habitat Conditions
Stream Condition
No Score
Not Functional
At Risk
Functional
Watershed Conditions
Functional
Degraded
At Risk


Planned Trend Scenario
Anticipated Habitat
Change
Stream Condition
No Score
Not Functional
At Risk
Functional
Planned Trend Change
Degrade
Maintain


Conservation Scenario
Anticipated Habitat
Change
Stream Condition
No Score
Not Functional
At Risk
Functional
Conservation Change
Degrade
Improve
Maintain


Moderate Scenario
Anticipated Habitat
Change
Stream Condition
No Score
Not Functional
At Risk
Functional
Moderate Change
Degrade
Improve
Maintain